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Influence of mechanochemical activation on the sintering of cordierite ceramics in the presence of Bi_2O_3 as a functional additive

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ABSTRACT

Due to its outstanding electrical characteristics, such as the low temperature expansion coefficient, low dielectric constant and good mechanical properties, cordierite, $2MgO\cdot 2Al_2O_3\cdot 5SiO_2$, is a very attractive high-temperature ceramic material. In order to accelerate the process of sintering, 2.50 mass% Bi_2O_3 has been added to the starting mixtures. Liquid phase sintering caused by the presence of bismuth-oxide lowers the temperature of cordierite formation. The mechanical activation of the starting mixtures (0–56 min in vibro-mill) additionally lowers sintering temperatures. The sintering process was performed at 1200, 1300, 1350 and 1400 °C, for 2 h. The particle size analysis (PSA) was employed in order to determine the changes in the particle size of the mechanically treated powders. The phase composition of the starting powders and sintered materials was analyzed by the X-ray diffraction method. Furthermore, scanning electron microscopy (SEM) was used in the analysis of the powder morphology.

1. Introduction

Cordierite, whose chemical composition is $2MgO\cdot 2Al_2O_3\cdot 5SiO_2$, is one of the phases of the ternary $MgO–SiO_2–Al_2O_3$ system, along with mullite, cristobalite, tridymite, enstatite, forsterite, sapphirine etc. [1]. Cordierite is widely used in glass–ceramic compositions for manufacturing multilayer circuit boards, catalytic converters, filters, kiln furniture, and thermal insulation materials [2]. Furthermore, because of the outstanding thermo-mechanical, chemical and dielectric properties of cordierite glass ceramics, they have been in use for decades in various fields, ranging from substrates for microelectronic packaging industry to cookware, heat exchangers and, more recently, glazes for floor tiles. Despite extensive research carried out in the fields of crystallization behavior, kinetics and properties of these glass ceramics, they are still under study [3]. Mullite glass ceramics have also attracted some attention in recent years because of their low thermal expansion, high mechanical strength and optical characteristics, and they have found diverse applications like dental porcelains, ceramic matrix composites and materials used in laser technology.

There are several methods to synthesize cordierite, such as solid-state reaction, sol-gel and crystallization from glass. Among these methods, sintering of oxide powders under the temperature between 1250 and 1350 °C through solid-state reactions or crystallization of glass powders is the most conventional, as reported by V. K. Marghussian et al. [4]. The same authors have established that the fabrication of cordierite–mullite composites via the conventional sintering route is very difficult because of the high refractoriness of these two materials (especially mullite). The addition of any sintering aids could adversely affect the thermal and electrical properties of the composite material.

Different processes remarkably influence the reactivity of the solids [5]. Mechanical treatments are important as long as they can help produce changes in the texture and structure of the solids, causing the particle size reduction and decreasing the reaction sintering temperature [6]. Additives can also decrease the temperature of the reaction process during sintering [7]. The application of additives should improve the contacts between reacting components. Therefore, cordierite is mixed with bismuth-oxide, which cannot be incorporated into the crystal lattice of cordierite because of its greater atomic radii [8]. The authors attempted to study the influence of both mechanical activation and additive usage on the cordierite formation during an isothermal sintering process at various temperatures.

2. Experimental procedure

Mixtures of MgO (98.60%, Euro Hemija), Al_2O_3 (99.19%, Aluminijumski kombinat, Podgorica), SiO_2 (96.10%, Bela Reka) and Bi_2O_3

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